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ABSTRACT

The experiment reported here attempted to investigate the nature of both intrinsic, unlearned temporal parameters as well as learned, language-specific durational properties in the speech of young children. Developmental aspects of several temporal parameters were investigated in the speech of ten 2 1/2 to 3-year-old and ten 4 to 4 1/2-year-old English-speaking Children; ten adults served as a control group. These parameters were: (a) overall word and segment duration; (b) voice onset time; (c) place of consonantal articulation and duration; (d) consonantal voicing and duration; (e) consonant effects on vowel duration; (f) effects of syllable position on vowel and consonant duration; and (g) effects of stress on vowel and consonant duration. Each subject produced ten repetitions of nine nonsense words. Both groups of children typically revealed word and segment durations which were longer than those of the adults, but speech segment durations of both groups of children reflected intrinsic properties similar in magnitude to those of the adults. Although absolute duration increments due to language specific variables were greater for the children than for the adults, both groups of children behaved very much like the adults with regard to proportional increments of segments. The only extensive departure of the children from adult durational properties was observed in the production of the voiceless stop consonant /t/. Despite various temporal differences between the speech of children and that of adults, it was concluded that children possess timing control systems which are more sophisticated than has previously been suggested.
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DEVELOPMENTAL ASPECTS OF ENGLISH SEGMENT DURATION

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A number of experimental phonetic studies have detailed the nature of durational properties of adult speech. However, very little such information is available from a developmental perspective. This is unfortunate since durational information is relatively easy to obtain and objectively quantify--in contrast to the generally speculative process of determining hypothetical underlying forms and phonological rules in child phonology.

As a preface to what I will report today, it should be noted that at some point early in the speech production process, individual segments are believed to reflect inherent durational properties (Klatt, 1976). At the output level of speech production, however, various factors have worked to modify these inherent segment durations. Basically, two general functions produce such temporal modifications. First, physical properties of the speaker's production mechanism impose intrinsic constraints on the inherent segment durations. These constraints are presumably unlearned and universal in nature. Secondly, the talker may intentionally modify these basic segment durations to provide linguistically-relevant information for the listener. These alterations represent learned, language-specific influences that are higher-order processes. One might reasonably expect even very young children's productions to exhibit the same intrinsic temporal properties observed in adult speech; however, in the case of language-specific durational factors, the child must presumably proceed through a period of development before mastering temporal characteristics unique to his native language.

The experiment I conducted represented an attempt to investigate the nature of both intrinsic, unlearned temporal parameters as well as learned, language-specific durational properties in the speech of young children. Unfortunately, time will not permit detailed discussion of each of the durational variables I considered; therefore, I will discuss only a few of the findings resulting from this study. However, for the sake of possible discussion at some later point, let me at least list the temporal parameters I considered. They were:

- 1) overall word and segment duration
- 2) voice onset time
- 3) place of consonantal articulation and duration
- 4) consonantal voicing and duration
- 5) consonant effects on vowel duration
- 6) effects of syllable position on vowel and consonant duration
- 7) effects of stress on vowel and consonant duration.

Thirty "normal" English-speaking subjects were involved in the study. Ten 2½- to 3-year-olds, ten 4- to 4½-year-olds as well as ten adults served as subjects. Each subject produced ten repetitions of the following nine nonsense words: /BAB/, /DAD/, /TAT/, /BAbab/, /DAdad/, /TAtat/, /baBAB/, /daDAD/, /taTAT/. These stimuli were randomly presented by the experimenter using live voice and the subjects imitated the experimenter's productions. The recordings were analyzed using oscillographic traces obtained from a Honeywell Visicorder.

The first issue of concern dealt with overall word and segment duration. Piecemeal evidence suggests the hypothesis that young children

may produce speech segments longer in duration than those of adults (DiSimoni, 1972). Research concerning maximum rate of syllable repetition (Fletcher, 1972; Irwin and Becklund, 1953), maximum rate of finger tapping (Dawson, 1929), the development of reaction time (Singer, 1973), and other such motor skills has indicated that such abilities improve from at least 2 up to about 19 years of age. It was important to assess this factor in order to obtain a perspective for interpreting the various phonological issues to be considered. That is, if children require longer to produce segments, there are at least two alternatives that might occur in the development of temporal phonological processes. Children might learn to modify segments in an absolute sense, equal in duration to adult performance; or they might make relative adjustments commensurate with their own rate of production. For example, a given vowel may have an inherent duration of 200 msec in adult speech, and a particular phonological process might lengthen it to 250 msec. This 50 msec increase represents an adjustment of 25%. If a child's inherent duration for that same vowel were 300 msec, the issue is whether the child would learn to lengthen the vowel by an amount comparable to the adult's absolute increment (i.e., 50 msec) or by the relative amount of 25%, which would represent a 75 msec increase. Knowing which of these alternatives might occur should help in better understanding the various phonological observations.

SLIDE 1

The first slide shows the average durations of the nine stimulus words for each group. Duration was measured from release of the initial stop to release of the final stop. It can be seen that for each of the nine words, duration was greatest for the two-year-olds and least for the adults. The average word duration for the four-year-olds was approximately 60-100 msec greater than the average adult duration; this represents approximately a 15% difference. The two-year-olds revealed approximately a 100-200 msec or 31% increment when compared to the adult values.

This strong tendency for the duration of words and segments to be inversely correlated with age closely parallels the previously-mentioned findings regarding age-related improvement of other aspects of motor performance, such as faster maximum finger tapping rate, and so forth. Such improvement of motor capabilities probably relates to increasing neuromuscular control which develops during the first 15-20 years of life. Knowing these age-related durational differences of 15% and 31% now makes it possible to investigate other phonological properties from an appropriate perspective.

Another issue I considered was the effect of place of consonantal articulation on duration. Research with adults suggests that the duration of labial stops is on the order of 20 msec longer than that of alveolar stops (Fischer-Jørgenson, 1964). Generally this difference is assumed to be a function of biomechanical aspects of the production mechanism (MacNeilage, 1972). If this is true, it would seem reasonable to expect comparable constraints to be evidenced in children's productions. When considering the average duration for labial vs. alveolar

productions for medial and final position in the present study, it was found that indeed all three groups of speakers revealed significant duration differences of 10-20 msec, in the predicted direction. However, when comparing across groups, no significant differences were observed. In other words, both the two-year-olds and the four-year-olds performed in a manner essentially comparable to the adults — probably due to unlearned, mechanical aspects of the production apparatus, rather than as a result of higher-order learning.

The next topic relates to the effect of consonantal voicing on duration. Evidence from both acoustic and physiological studies suggests that closure duration differences exist between so-called "voiced" and "voiceless" consonants (Lisker, 1957; Slis, 1971). Available information from adult research is somewhat inconclusive as to whether such differences stem from learned, language-specific, factors or from intrinsic, physical causes. In the present study, when averaging over all medial and final position occurrences of /t/ and all occurrences of /d/, /t/ was found to be 17 msec longer in duration than /d/, for the adults. This constitutes approximately a 20% difference between these two segments. For the four-year-olds and the two-year-olds, the duration difference between /t/ and /d/ was on the order of 60 msec, which represents a 60-70% difference. Of all the phonological issues considered, this particular case represents the only example of a major absolute and relative duration difference occurring across ages. That is, all three groups did not evidence the same durational relationship between the segments /t/ and /d/.

If we consider these data with regard to the previously-mentioned child/adult ratios of 15% and 31% longer durations for the two groups of children, an interesting observation can be made. In the case of /d/ productions, the duration increments for both groups of children were approximately comparable to the age-related 15% and 31% increments. In this instance, such differences are probably attributable to differences in neuromotor control capability alone. In the case of /t/, however, both groups of children evidenced approximately 40% longer segments than the average expected differences of 15% and 31%. In this case, the duration differences between the children and the adults were extensive enough to suggest that more than general age-related neuromotor factors may have been involved.

It is difficult to determine whether this striking difference in duration between /t/'s produced by the adults and those produced by the children involved a production constraint or whether it served a linguistic function. Because stop consonants produced by children frequently tend to be "devoiced," a durational increase such as this may have been intentionally produced to perceptually enhance the /t/-/d/ distinction. On the other hand, the rather vague notion of "production difficulty" could have facilitated such durational differences. For instance, it is possible that the overly long closure duration of /t/ for the children was necessary in order to coordinate glottal and supraglottal gestures required for the production of voiceless, aspirated stops. Because no active glottal adjustments

are required for producing /d/, however, it might in some way represent a less complex production, and hence it would be "easier" to approach adult-like output characteristics.

Let me briefly summarize the results of the next section concerning consonantal effects on vowel duration and syllable-level effects with the following slide.

SLIDE 2

As previously noted, the duration of the consonant /d/ was shorter than that of /b/ for all three groups; however, vowels preceding /d/ were longer than vowels preceding /b/ by essentially comparable amounts. Similarly, the duration of /d/ was found to be shorter than that of /t/ for all groups, but vowels preceding /d/ were longer than vowels preceding /t/. In all cases, the relationship between the duration of closure for /b/, /d/, and /t/ was virtually the inverse of the relation between vowel durations in those particular environments.

Although these results are perhaps more sensitive to measurement criteria than certain other issues, the effect of this is that such relationships tend to equalize the duration of given vowel plus consonant sequences, even across intervening syllable boundaries. This is shown in the following slide.

SLIDE 3

Regardless of individual vowel and consonant duration differences, the three types of V + C sequences involved in this particular study were of approximately equal duration within each group of subjects.

Another issue considered in this study was what is typically referred to as "final syllable vowel lengthening" (Oller, 1971; Delattre, 1966; Lindblom, 1968). Research with adults has shown that vowels occupying the final syllable position of a phrase or utterance are as much as 100 or more msec longer than comparable vowels in non-final syllable position in English and other certain languages. Whether this lengthening is a function of language-specific learning or intrinsic properties of the speech production mechanism remains somewhat unclear based on available data from adult research.

SLIDE 4

The next slide depicts the relationship which was found to exist between final and nonfinal syllable vowels for the two groups of children and the adults in this study. In all cases, similar results were evidenced by each of the three groups, viz., final vowels were 100+ msec longer than non-final vowels. This represents a 60-70% increment in final position. However, when comparing the three age groups, it was found for both absolute and relative vowel duration relationships that very few statistically significant differences occurred.

Had the children performed noticeably different from the adults, it would be reasonable to suggest that they simply had not learned the

principle of final syllable lengthening. However, obtaining positive findings such as these does not allow a definite conclusion as to whether early phonological learning has occurred or whether intrinsic, physical factors produced such lengthening. Additional findings from a pilot study are of some interest in this regard, however. A number of meaningful CVCV utterances produced by a 13-month-old and by an 18-month-old revealed final syllable vowel increments very comparable to those of the children and adults in the present study. Although open rather than closed syllables were involved, the amount of lengthening was extensive enough to suggest the conclusion that even as early as 18-months of age or younger, considerable final vowel lengthening can be observed in children's utterances. Again, although this apparent positive finding makes it difficult to decisively determine the source of final syllable lengthening, one must recognize that if it is a learned phenomenon, final syllable vowel lengthening must develop as an extremely early aspect of the child's phonological system.

With regard to the effects of lexical stress on vowel duration, it was again observed that very few significant absolute or relative differences existed when comparing across the three age groups. I will not take time to detail specific effects other than to show the next slide.

SLIDE 5

The average absolute difference between stressed and unstressed vowels was in the range of 30-60 msec for all three groups of subjects, which represents approximately a 20-30% increment.

Although a number of individual temporal parameters were observed to reflect relatively early development of adult-like characteristics, an even more striking example of similarity between the performance of both groups of children and the adults can be observed by considering the interactive effects that stress and syllable position combined were found to exert on vowel duration.

SLIDE 6

The next slide indicates that stressed, final vowels represent the maximum durational effect of stress and syllable position combined; thus they are assigned a value of 100%. The other three combinations are shown as percentages of this maximum situation. For all three groups, stressed, nonfinal vowels are approximately 60% of the maximum duration. Unstressed, final vowels are about 80% as long as the maximum. For the unstressed, nonfinal situation, all three groups showed vowels about 50% as long as the maximum. In no case did the three groups differ from one another by more than 5%. This seems to indicate that the children exhibited a relatively high degree of temporal control, which allowed them to accurately govern the interaction of these temporal parameters.

In conclusion, I should say that at the outset of this study I fully expected to uncover a number of developmentally-oriented temporal differences for the parameters I chose. I expected that not even 4-4½ year old children (much less 2½-3 year old children) would have accurately developed many of the temporal parameters of their language (especially in the case of non-phonemic variables). At the time of analysis I was initially quite disappointed to find that--with the exception of the overly long duration of /t/--no other major differences between the temporal patterns of the adults and children were observed. Most other studies of children's temporal performance, as well as the numerous transcription-type analyses of children's rule systems, substitution patterns, etc., have tended to either explicitly or implicitly convey the impression that children require a number of years to conform to the adult model they are striving to achieve.

Although some absolute duration differences were observed in the present study (and they were probably related to general aspects of neuromotor control capability), the large number of relative similarities among the temporal patterns of the three groups was surprising. There are at least two possible explanations for such an observation. The strong hypothesis of the first says it is conceivable that there are basic, universal temporal patterns that exist for parameters such as final syllable lengthening or stress, and that the similarities observed among the three groups of subjects were nothing more than the result of these natural patterns of production. In other words, perhaps the children performed like the adults because no learning was

really necessary. Of course, the fact that different patterns exist for other languages would require explanation, but this can be done — it would, however, take us too far afield at this point.

The strong hypothesis of the second possible explanation for similar child and adult durational patterns is that even prior to three years of age, young children are able to recognize important temporal relationships in the language they are learning and incorporate them into their own phonological systems. This would indicate that at least at the level of the temporal domain of speech production, children possess more highly sophisticated systems than we have previously realized. As in most instances, the best answer is likely to be found in a somewhat weakened version of some combination of these two hypotheses.

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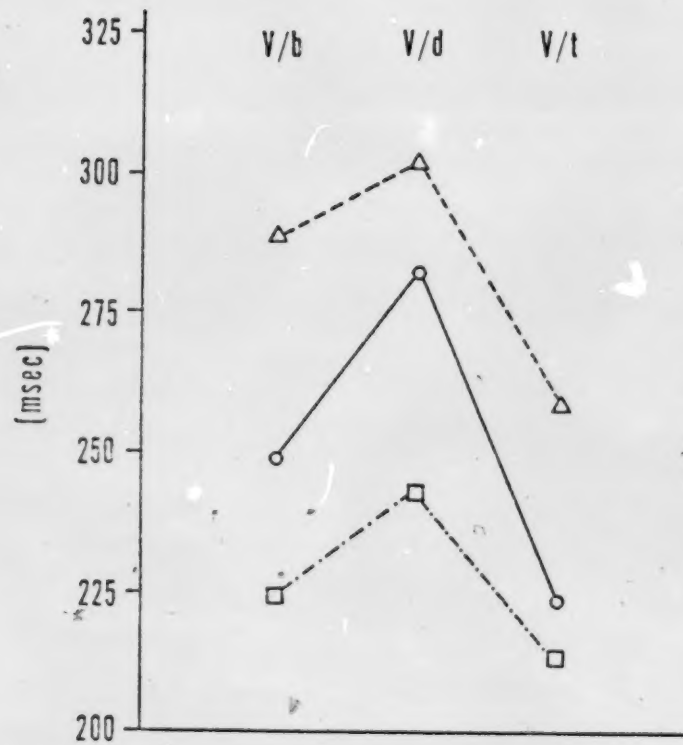
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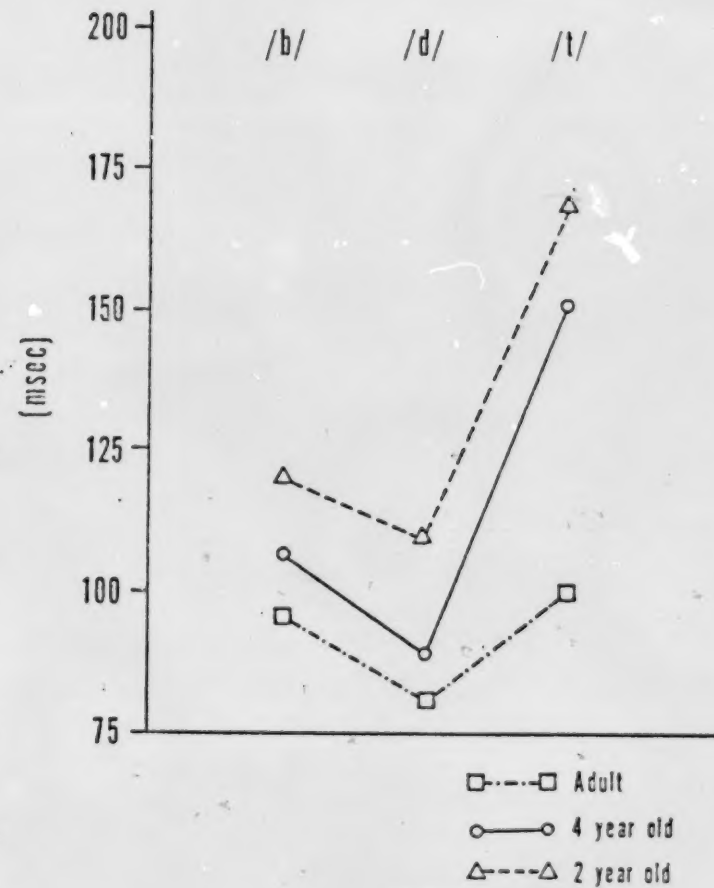
	<u>ADULT</u>		<u>4-YR.-OLD</u>		<u>2-YR.-OLD</u>	
	<u>$\bar{X}$</u>	<u>SD</u>	<u>$\bar{X}$</u>	<u>SD</u>	<u>$\bar{X}$</u>	<u>SD</u>
BAB	404	44	444	44	513	80
BAbab	577	46	631	55	735	146
baBAB	616	64	703	65	802	122
DAD	417	48	476	51	514	82
DAdad	580	50	651	56	742	139
daDAD	628	55	729	59	808	121
TAT	385	50	463	46	516	47
TAtat	588	58	684	48	789	121
taTAT	595	68	731	57	853	103

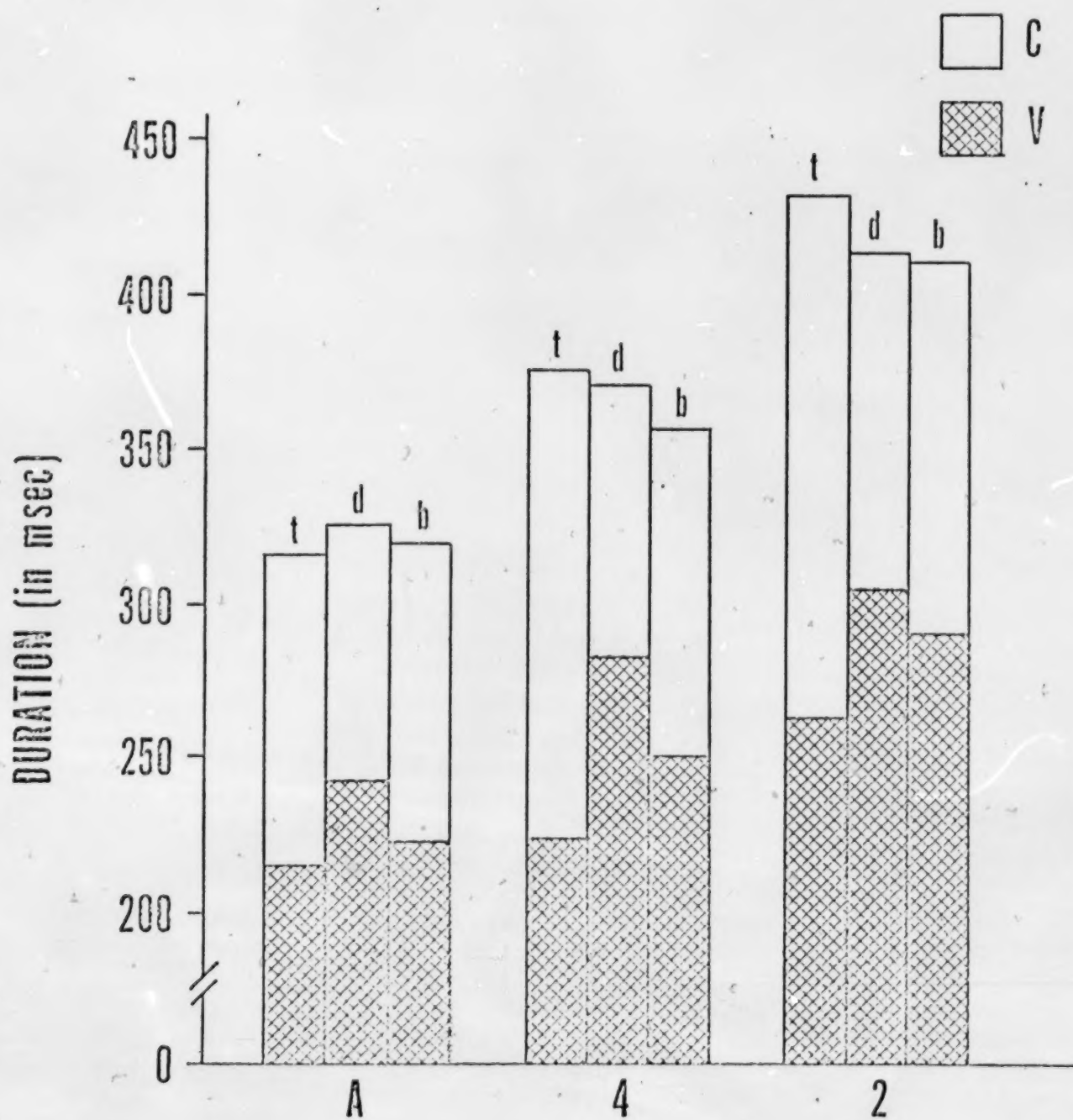
Average durations (in msec) and standard deviations of nine stimulus words

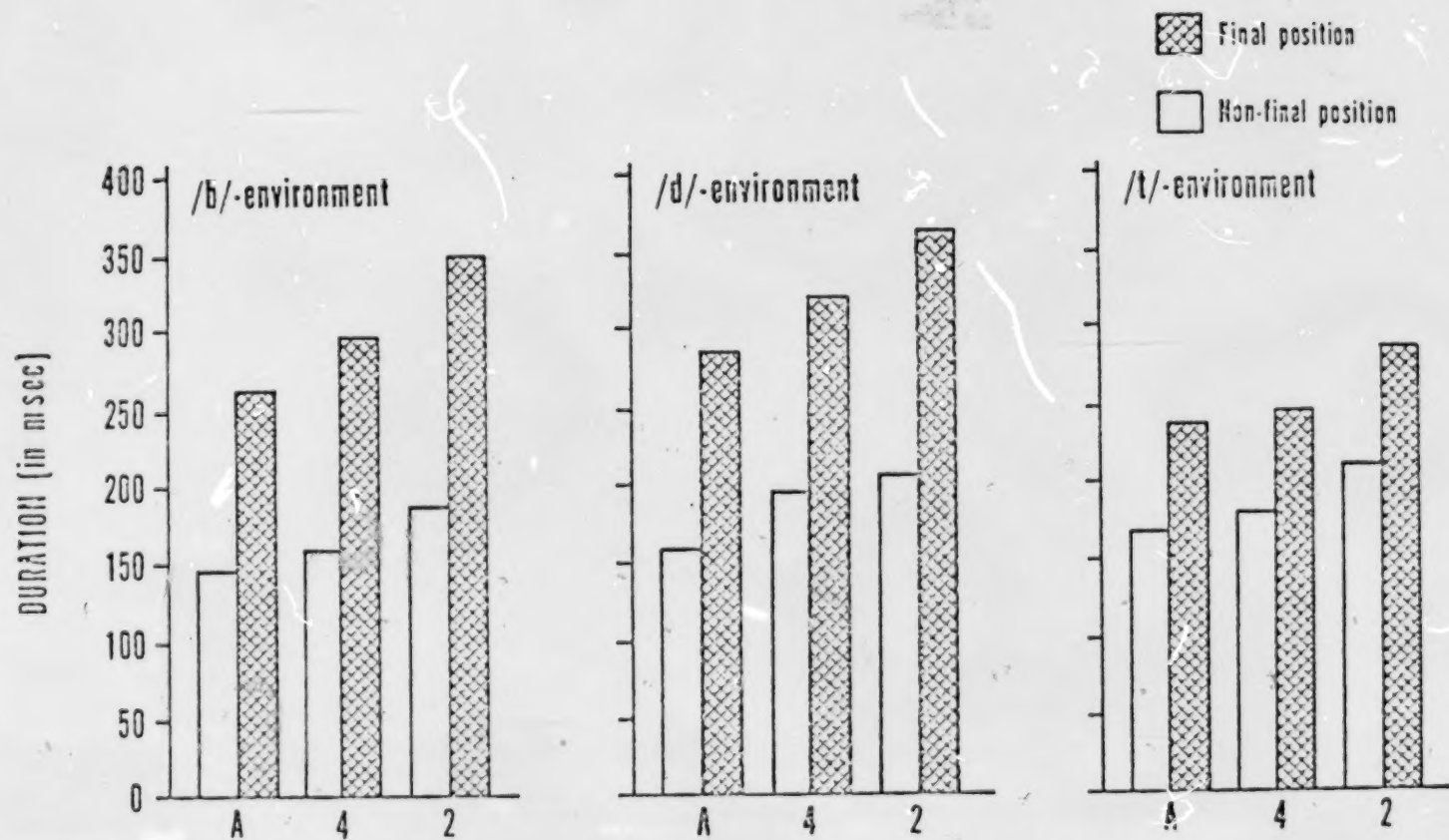
VOWEL DURATION (all positions)

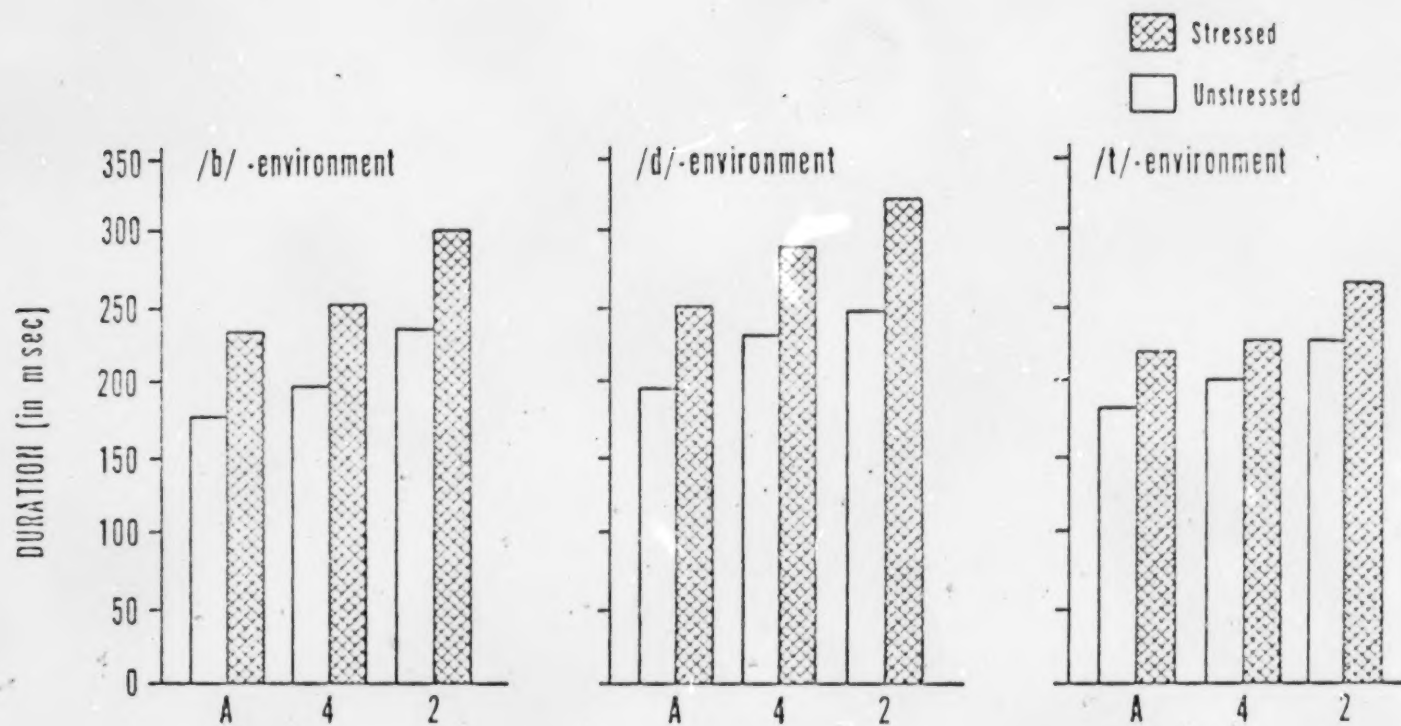


CONSONANT DURATION (all positions)









VOWEL DURATION

		(msec)		(per cent)	
		STRESSED	UNSTRESSED	STRESSED	UNSTRESSED
NON-FINAL	A	178	137	61	47
	4	188	170	58	52
	2	219	186	59	50
FINAL	A	291	233	100	80
	4	324	249	100	77
	2	373	288	100	77

Combined effects of stress and
syllable position on vowel duration